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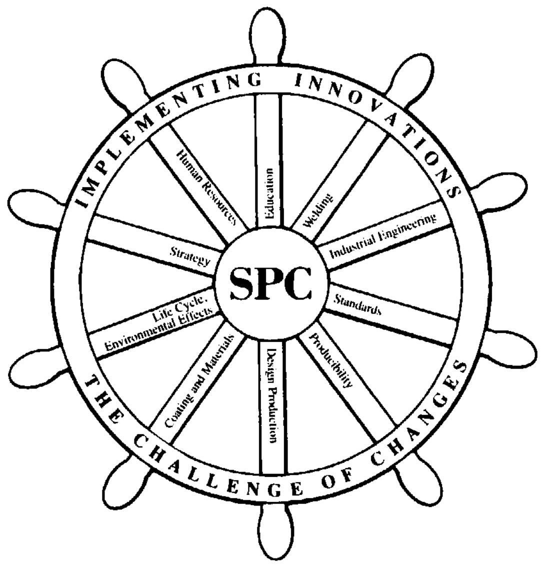

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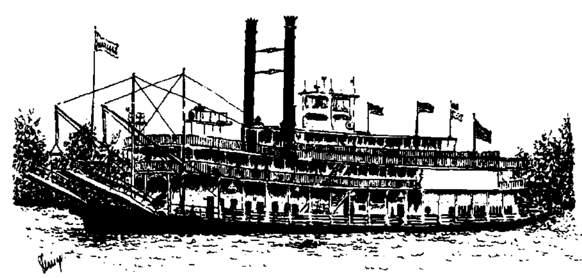

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The Effective Use of CAD in Shipyards

No. 2B-2

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ABSTRACT

In the current severely competitive climate that is challenging shipbuilders everywhere, how information is managed is taking on extraordinary importance. Existing computer aided design (CAD) systems have not been focused on the most critical information needs, for example, information to serve marketing. This limitation is the result of concentrating primarily on aspects of design and manufacturing without regard for impact on an overall manufacturing system. In this paper the need to extend CAD systems is identified so that they would more fully provide critical-data to everyone who has to have understanding of a manufacturing system's capability and availability.

INTRODUCTION

This paper is an attempt by the authors to provide a thought provoking preview of shipyard CAD systems for the next decade. It is based-on interviews, visits, and/or discussions with shipyard representatives from the U.S., Europe and Japan concerning current CAD capabilities and practices. It also reflects a review of pertinent CAD literature, in the marine and other industries. Finally, it considers CAD utilization and implementation issues in conjunction with the application of a modern, product oriented shipbuilding system which constantly improves while serving commercial-ship and other customers, in a worldwide competitive market.

Evidence is continuing to accumulate which indicates that even the most impressive CAD capabilities will never achieve their maximum potential if future such developments proceed as they have thus far. Most people who are responsible for funding existing and future CAD systems, still do not have sufficient understanding that the computerization of design, in what is now being called the information age, cannot proceed isolated from all other aspects of a manufacturing system per se.

Where such understanding exists, shipyard managers oversee rationalized work, exploit statistical analyses, provide information to workers about how their work is performing (especially regarding schedule, man-hour budget, and quality adherence), and rely on decentralized decision making. As top priority measures they insure that their manufacturing systems capture the many small-scope productivity improvement-ideas that-informed workers make. "At Ishikawajima-Harima Heavy Industries (IHI) each-employee submits an average of 18 suggestions for improvement per year." (1)

Thus in a shipyard which employs 1500 workers, 27,000 suggestions per year or about 120 per workday are considered. Collectively they are the "backbone" of the yard's constantly improving manufacturing system. But there would be no backbone if the impacts of accepted suggestions were not captured as corporate data, summarized at various levels, and instantly made available to managers, supervisors, and workers commensurate with their responsibilities. All are dependent upon knowledge of how their manufacturing system currently performs. Prominent among them are the marketing and estimating people who regularly project the rate of improvement and discount bids for contemplated projects accordingly. Emphatically, for world-class performance, CAD system developers have to address how to automatically assimilate the consequences of every design and manufacturing method change regardless of its size. Furthermore, the information age requires CAD system developers to regard marketing as part of the manufacturing system because it is vital for marketing people to be precisely up to date about the system's capability and availability.

As shown in Figure 1 the feedback paths to marketing from the other basic management functions (planning, scheduling, executing, and evaluating), constantly update knowledge of the manufacturing system's capability and availability. Estimating is an aspect of marketing. Design is an aspect of planning. Executing includes both material marshaling and producing.

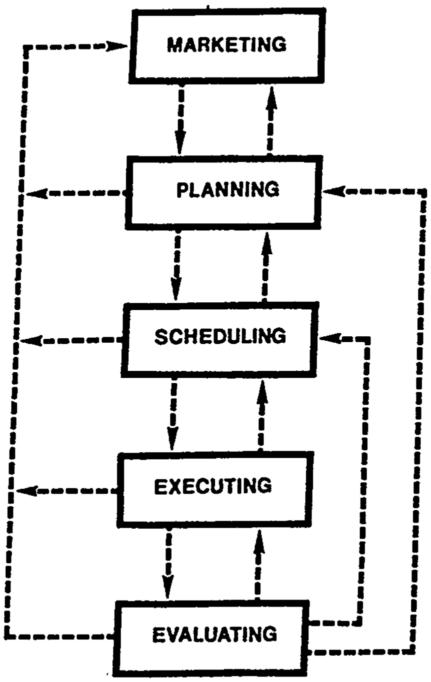

FIGURE 1: FEEDBACK PATHS TO MARKETING.

MARKETING NEEDS

No one will disagree that marketing is important, but because it is not generally recognized as part of the shipbuilding system, it has not benefited from marine industry related research and development efforts. Unfortunately, good advice was ignored. In the mid seventies when the National Shipbuilding Research Program (NSRP) was recognized in a Rand Corporation report as one of the most effective research programs funded by government, Marvin Pitkin, then a deputy administrator for the U.S. Maritime Administration and someone having significant experience in high-tech industry, advised, "The NSRP is doing a great job on half the equation, that is, the half that involves cost reduction." He went on to describe the need to also invest in developing marketing and, with Figure 2, emphasized that the NSRP should measure its success by monitoring the <u>difference</u> between shipyard revenue generated and cost incurred. This difference is a true measure of the success of a manufacturing system. Thus, marketing, which uniquely concentrates on increasing revenue, is critical.

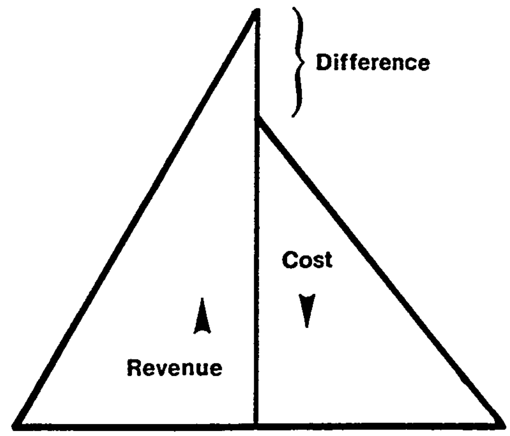

FIGURE 2: DIFFERENCE BETWEEN REVENUE AND COST.

The few in the U.S. shipbuilding industry who appreciated the need to support marketing, were soon diverted to lobbying for part of the program to build a 600-ship navy. At that time building warships was not compatible with development of a modern flexible manufacturing system which could manifestly self improve during each construction effort, and which could construct both naval and commercial ships and other entities, such as, processing and toxic-waste incineration plants. Work for customers with such understanding is essential for developing a modern manufacturing system, which in turn is essential for generating and constantly updating information that marketing people need in the information age.

Information that serves marketing that depends on input from design includes:

o how hull construction man-hours vary with block coefficient,

o how outfitting man-hours vary with block coefficient,

o how hull construction, outfitting, and painting man-hours vary with design and production innovations, and

accuracy expressed in statistical terms that the yard's manufacturing system normally achieves for various structural details.

Regarding block coefficient, hull construction man-hours reduce and accuracy improves as line heating is perfected for curving hull plates and structural shapes. Also, the engine rooms of high-speed container ships are more difficult to assemble than those in tankers. An innovation, already implemented by a Japanese shipyard, features container-size outfit modules for the assembly of engine rooms. The yard specializes in production of the modules and transports them in container ships to other yards, in Japan and elsewhere, for blue-sky outfitting. When the accuracy normally achieved is referenced in contracts, enlightened owners who understand the link between productivity and quality are thus assured that critical dimensional requirements, as in container and liquid natural gas ships, will be met. Also, regulatory agencies are assured before work starts of structural integrity that is related to accuracy, for example, the alignment of longitudinal butts.

Keeping marketing people up to date about such relationships is very important because even the slightest edge in a market that includes constantly-improving competitors, is vital.

There is more information that marketing people need which should be the subject of development at least equivalent to that which has been applied for CAD in the last decade. Some needs were identified by Sarabia and Gutierrez in their description of the process of recovery which enabled Astilleros Espanoles, S.A. to reenter the global shipbuilding arena. (2) They described a strong marketing effort consisting of: training a large specialized sales force to canvass the world, sophisticated media and image campaigns, untiring travel for contacts with brokers and customers, and, as very important, "financial engineering teams that were brought in to prepare competitive offers, making the best of Spain's currency, exchange rates and credit schemes." Regardless of what computerization in shipbuilding is called, CAD extended or preferably, computer integrated manufacturing (CIM), financial matters, including ways to evaluate the quality of a prospective customer's fiscal responsibility, is the area that should now be targeted for highest-priority computer-application development.

While it may seem mundane to some, it is also critically important that CAD systems address many indicators of productivity that are not now being monitored, particularly in yards that have been favored with large naval shipbuilding programs. While their managers often cite learning curves that reflect the decrease in overall man-hours required per ship during series construction, and even by man-hours per ship's functional system, that information is not sufficiently detailed for practical management by target. When world-class shipbuilders shifted to product orientation, they reorganized people so that each group of designers has a counterpart group in production with whom they share responsibility for the cost of specific interim products. Thus both are immediately interested in monitoring many things for which design input is required and which are readily counted or calculated by simple computer routines; see Figure 3 for examples.

EARLY CAD DEVELOPMENT

Why didn't development of computer-applied management information systems in the 1960s direct CAD developers in the West to anticipate more than design needs? In the late 1970s when the first descriptions of a Japanese developed product work breakdown structure (PWBS) for shipbuilding were published by the NSRP, archaic system-by-system work breakdowns for implementation by inadequately-coordinated functional crafts, were in general use. The concept of a rationalized manufacturing system featuring integrated structural, outfitting, and painting work, was unknown as was the concept of collecting cost per (interim) product regardless of the mix of systems represented. Computerization of management information needs reflected the status quo. Even now, more than a decade later, only two U.S. shipyards demonstrated with completed shipbuilding projects that they organized information, people, and work, with sharp focus on cost per product.

Without such demand from managers, design oriented people a0 not understand that the effective use of CAD is not limited to improving the effectiveness and efficiency of the design process. With such demand they will understand that they can significantly contribute to improving the effectiveness and efficiency of the entire shipbuilding process which includes all design activities. Furthermore they will readily accept that for building a typical merchant ship, basic designers, those who interact the most with marketing people, only contribute 3% to direct costs, whereas by a wide margin,

a. ratio of net steel weight to invoiced weight,
b. number of hull plates and percentage of curved plates,
c. ratio of penetrations NC cut to total number of penetrations required,
d. total lineal meters of hull erection butts and seams,
e. total lineal meters and locations of erection butt and seam edges that were not neat cut,
f. total lineal meters and locations of erection butts and seams that required rework by gas cutting and, separately, that required rework by back-strip welding,
g. accuracy in terms of mean values and standard deviations for hull parts, sub-blocks, blocks, and erection butts and seams,
h. number of temporary lifting pads required for hull construction,
i. number of scaffolding planks required separately for assembling bow blocks, midships blocks and stern blocks; for hull erection; and for outfitting separately by deck, accommodation, and machinery,
j. total lineal meters per size and type of welds for sub-block assembly and separately for block assembly,
k. total number of separate material items that must be manufactured or purchased, and the numbers that apply for each specialty, for example, deck, accommodation, machinery, weapons, etc.,
1. lineal footage of all pipe and separately for large, small and medium diameters, (This item and most which pertain to pipe that follows, also apply to vent-duct pieces.)
m. number of pipe pieces and percentage of field-run pipe pieces (The latter represents work out of control and is a particular target for reduction.),
n. average pipe piece length,
o. number of straight pipe pieces and pipe pieces that can be completely fabricated as straight and bent afterwards (these are the two least-cost categories),
P. number of bent pipe pieces having other than 90 and 45 degree bends (Allowing other degree bends impacts adversely on ability to employ statistical accuracy control.),
q. number of bent pipe pieces which require less than "3-diameter" radius bends (Smaller radii impact adversely on ability to employ statistical accuracy control.),
r. number of pipe pieces fitted on unit, number fitted on block, and number fitted on board.
s. number of pipe pieces that must be fitted on board of such weight and/or length that exceed limits determined from what one worker can handle safely.
t. regarding pipe-piece precision, ratio of total number of mock, loose flange, reworked, etc. pipe pieces to total number of pipe pieces (This too is a particular target for reduction.),
u. accuracy in terms of mean values and standard deviations for pipe pieces,
v. footage of all electric cable and separately for small, medium and large diameters,
w. footage of electric cable pulled on block and separately for small, medium and large diameters,
x. number of electric-cable runs and separately for small, medium and large diameters,
y. number of electric-cable runs precut and separately for small, medium and large diameters,
2. number of electric-cable runs pulled on block and separately for small, medium and large diameters,
aa. number of precut electric cable runs provided with distance from the pulling end to a reference mark to facilitate installation (This also requires, dimensions for corresponding reference marks on-block or on-board.) and separately for small, medium and large diameters,
bb. percentage of electric cable pulled on block relative to total footage of cable required,
cc. percentage of cable ends connected on block relative to total cable ends connected,
dd. average length of remnants from precut cables separately for small, medium and large diameters,
ee. total number of supports for walkways, pipes, vent ducts, electric-cable trays, etc., and
ff. regarding material pallets, ratio of missing line items to total number of line items.

FIGURE 3: EXAMPLES OF PRODUCTIVITY INDICATORS THAT SERVE MANAGEMENT BY TARGET.

they have the greatest influence on ship total cost. Thus, compared to traditionalists, the world's most effective shipbuilders invest more in basic designs and insure that each design is implemented as an aspect of planning. When shown Figure 4, which illustrates that basic designers have the greatest influence on ship cost, a former managing director of Australian Defense Industries said, "When a project is behind schedule and/or over budget, do not blame production. First ask, 'Who is responsible for the planning?'"

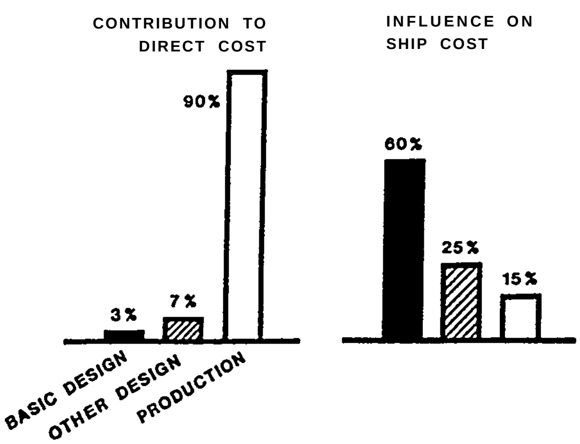

FIGURE 4: IMPACT OF DIRECT-COST ON SHIP COST.

Most shipyard CAD systems evolved over a number of years, forcing managers to decide between upgrades to existing hardware/software or total revamping of an outmoded system. Rarely did shipyard managers choose the later approach. Consequently, most CAD systems are the outgrowth and extension of earlier systems. In shipbuilding, the initial application of CAD systems was for computer lofting. There are a number of systems that fit this description. Originally, design/lofting contractors provided numerical control (NC) tapes for the shipyard to use for automatic control of cutting machines. The next upgrade involved the direct generation of the NC tapes at the shipyard, and thus involved the installation of a CAD system that was capable of producing information to generate the NC tapes. Systems are also currently in operation that electronically transfer NC cutting instructions to the cutting machines without generating tapes. The early literature (from 1975) about CAD systems reflects the concentration on steel parts cutting. (3,4) Eight years later, in 1983, although computer hardware had significantly improved, the concentration was still on steel parts design and production, with additional emphasis on structural computations. (5,6)

Had hull construction processes in Western shipyards been rationalized before computerization, per the Pareto principle, initial developmental efforts would have been directed at subassembly, block assembly and hull erection work. That would have addressed about 90% of hull construction man-hours as compared to parts production (10%). This different focus would have established identification of process control through statistical analysis of accuracy variations as far more important than just improving parts production. Something as simple as a fish-bone (cause-and-effect or Ishikawa) chart applied for improving any assembly work, would have shown that the need for improving the accuracy of parts did not make sense if not compatible with fitting and welding capabilities for subassembly, assembly and erection work. Why improve parts "accuracy" if no compensation is made for shrinkages caused by gas cutting and if margins of excess material (commitments to rework) are routinely employed? Thus 25-years ago, computerization of hull construction processes in Japan lagged relative to that in the West while the statistical approach, very much of which was performed manually, permitted Japanese shipbuilders to eliminate virtually all margins and to constantly establish the latest criteria, in statistical terms, for further automation of welding. Computer applications independent of a unified CIM system were developed in support of these narrower, but higher-priority needs, such as statistical accuracy control. (7,8)

In the West, simultaneously with the development of NC for parts cutting, CAD capabilities that were primarily useful-for drafting were being developed. These systems provided the opportunity to develop high quality, preliminary design drawings, such as outboard profiles, general arrangements and machinery arrangements. Additionally, CAD drafting capability was used to do on-screen detail design, permitting uniformly high quality drawings to be produced. Similarly, CAD development in Japan focussed on software modules for specific detail design applications. Shipbuilders developed internal systems for design of Structure, piping, accommodations, etc. **(9,10)**

CONTROL THROUGH CONTROL OF MATERIAL

In the absence of a PWBS with its sharp focus on cost per interim product, most computer applications in the West were developed in the mold of traditionalism leading one wit to note, "A computer lets you make more mistakes faster than any other invention in human history, with the possible exceptions of handguns and tequila." (11) The computerization of cost/ schedule control based on collection of data by ships' functional systems is the most profound example. In order to postpone hassles, supervisors in such traditional environments regularly mischarge man-hours and/or report progress, as a crisis deepens, through increasingly-darker rose-colored glasses. Of course, computer prepared summaries of such data misinform managers faster than they have been misinformed before computers were introduced.

But with product orientation as developed in Japan, first priority was assigned to employing computers for production control through control of material. Monitoring material definition from establishment of a material budget during marketing to producing structured material lists down to the level of the smallest assemblies (as for pipe pieces) started many years ago and is still regarded by the world's most effective shipyard managers as their most important computer application. The man-hours needed for processing materials are, as a consequence of corporate experience, related to physical characteristics of material. Thus basic man-hour budgets, and therefore basic schedules, are computer produced. As the material is further defined during each design stage which follows a marketing effort, computers constantly monitor for the purpose of answering two questions. Compared to materials defined previously, have any new materials been defined? Has there been any change in quantity of any material item previously defined? Affirmative answers to one or both during any design phase automatically advises of the basic amounts to change the man-hour budget and the schedule.

Further, in accordance with a strategy provided and refined by production engineering functionaries, detail designers group information (arrangements and details and attendant material lists) to match what is to be assembled in a specific zone during a specific stage, such as for assembling an outfit unit or for a discreet amount of outfitting on block. The same parameters which relate materials to man-hours required for their processing are used in Japan, per U.S. Department of Defense parlance. for establishing <u>budgeted cost of work scheduled</u>, and when workers "shade in" material lists as materials are processed. for determining <u>budgeted cost of work performed</u>. For the bulk of the materials processed, no supervisor's assessment of work performed is required. Computerization of design in the most effective yards in Japan contributes significantly to cost/ schedule control!

With the extraordinary focus on grouping material to match interim products in Japanese shipyards, computer applications for material management were given extraordinary attention. The number of prospective suppliers for any one material requirement was limited in order to make practical the maintenance of required knowledge, that is, design details, regulatory approval status, timely delivery record, previous costs; vendor guarantee history. various material classifications, etc. Generally, twice the computer capacity required for design was devoted to material management matters. Further it made practical computer files of flexible standard arrangements and details that CAD operators could "plug in" and that production managers could use for collecting attendant cost and schedule adherence data.

Notice of this profound computer application was published fourteen years ago when Ichinose advised:

"It is obvious that a comprehensive computerized design system, consistent from design through production, could not be effectively realized without standards or modules."

"Standards and modules show their greatest advantage when integrated with a comprehensive computer system." (12)

The modules described by Ichinose also applied to diagrammatics. (13)

Standards and modules were included in Future-Oriented Refined Engineering System for Shipbuilding Aided-by - Computer (FRESCO) as briefly described in a paper which was presented three-years ago. FRESCO is having a profound beneficial impact on the sponsoring company's overall manufacturing system. (14)

Also, computer capability makes it easy to enter changes and quickly produce updated high-quality drawings. While this CAD capability was extremely useful for marketing, in-general there was no capability to automatically extract and discuss previously used diagrammatics or standard arrangements.

As a matter of equal significance, the drawings from these systems used for contract design could not be electronically transferred in order to start the next design stage. In other words, links between the CAD drafting tools and the NC lofting tools did not exist.

A major area of development in CAD systems over the past decade has been the linking of structural design software packages with outfit design packages for piping and electrical distributive systems and for heating, ventilation, and air-conditioning systems (HVAC). Significant progress has been achieved, although the goal of most applications has been interference checking after sequential design has taken place (structure, piping, HVAC, and electrical in that-order):.Thus,. while CAD capabilities have continued to increase exponentially, Western shipbuilders have not had the benefit of system development focussed on the most critical needs of the overall shipbuilding system. (15,16,17)

Again, this lack of insight is due to not rationalizing shipbuilding work, which would have led to general adoption of PWBSs.

3D MODEL

Commonly, after CAD drafting tools are used in the contract design stage, a new, large scale effort must be started to develop a 3-dimensional (3D) model of the shell, major structure and major outfit components (including space reservations for distributive systems). The development of the 3D model can require about a 6 to 12 man month effort, for a basic model of a large ship. Today, many shipyards have separate systems for preliminary design and detail design. These systems are often totally incompatible, or can transfer data only with considerable effort.

In other words, the computer capabilities are not used to address the full management cycle from marketing (including estimating to evaluation. Furthermore, the incompatibility between systems commonly used for basic and sometimes system design and those used for transition and detail design impedes both the rapid progression of the design process and the availability of feedback from the later stages of design and more importantly the management cycle.

The key means of relating information at all stages of the management cycle is through interim products, i.e. material.

If a CAD system is intended to provide maximum benefit to a shipyard, it must effectively address the critical information needs of all facets in the yard's manufacturing process. Discussion of the need to consider total integration of the shipbuilding system began some time ago. These have focussed on the life cycle of the vessel or additional coordination with management information systems. No consideration of the need to include marketing decisions is commonly included. (18,19)

Since marketing is the initial stage, CAD capability must focus on generating information that is descriptive in terms of ship capability/cost tradeoffs. Since many iterations and options will commonly be considered, rapid, easy response is a key requirement. Even though the 3D model would provide more information at the initial stage, the cost for generating a 3D model for each product alternative under consideration, would not be justified. Thus, at the initial stage, 2D capability is the proper choice. This reflects existing practice in nearly all shipyards evaluated by the authors.

Although drawings based on 2D information are all that are required at the marketing stage, many systems exist that have the same rapid response and ease of use, but that also provide direct transfer of information for the 3D modeling required later. Thus. phasing out the use of strictly 2D systems in favor of systems that permit easy transition to 3D models is prudent. The primary reason for suggesting this is not the ease in generating the 3D model for later stages of design, however. Compatibility between marketing CAD tools and detail-design CAD tools is essential to permit electronic data feedback to provide marketing and estimating people with current information concerning actual cost, including cost comparisons between alternatives. Additionally, a key benefit to marketing and estimating people is the development of a data base of reusable designs. In particular, "standard" diagrammatics are valuable as a starting point for discussions with potential customers, and could be quickly developed to be included in contract design packages.

The timing for preparation of each 3D model is somewhat important, because it involves a significant investment. It is also an important initial step for the transition design process, and thus its early development-facilitates producing material lists for pallets sequenced by the specifically designated build strategy. Thus, rapid

start of production depends on early development of a 3D model. While a 3D model can be developed at various locations within the design organization, it has a distinct tie in to marketing. Only marketing and contract negotiation people have direct contact with potential customers, and therefore should have a good feel for when a contract has a high probability of being signed. Additionally, they have more intimate knowledge of customers' needs and wants. Furthermore, the generation of a 3D model is likely to occur rather infrequently. Thus, centralization of this skill in close proximity to marketing will offer the advantages of good communication and coordination between marketing, design and material procurement functions.

BASIC SCHEDULING

A significant part of the feedback to marketing from design and production relates to current information regarding cost, and thus is useful for helping evaluate cost/capability tradeoffs. The second key piece of the equation, schedule, can also be addressed in a CAD system that has been designed to serve marketing through feedback of current information.

As previously mentioned, basic schedules can be computer produced as a part of the marketing effort, using the relationships of physical characteristics of material to man-hours and time durations normally experienced to process material. A second important type of feedback that could then be exploited is the current and anticipated utilization of the facility, by process lane. In this regard, production control data would indicate the progress of work by process lane for projects underway. Feedback to marketing resulting from reduction of information from a large-frame sense to small frame is shown in Figure 5. Both capability and availability information are included. (20)

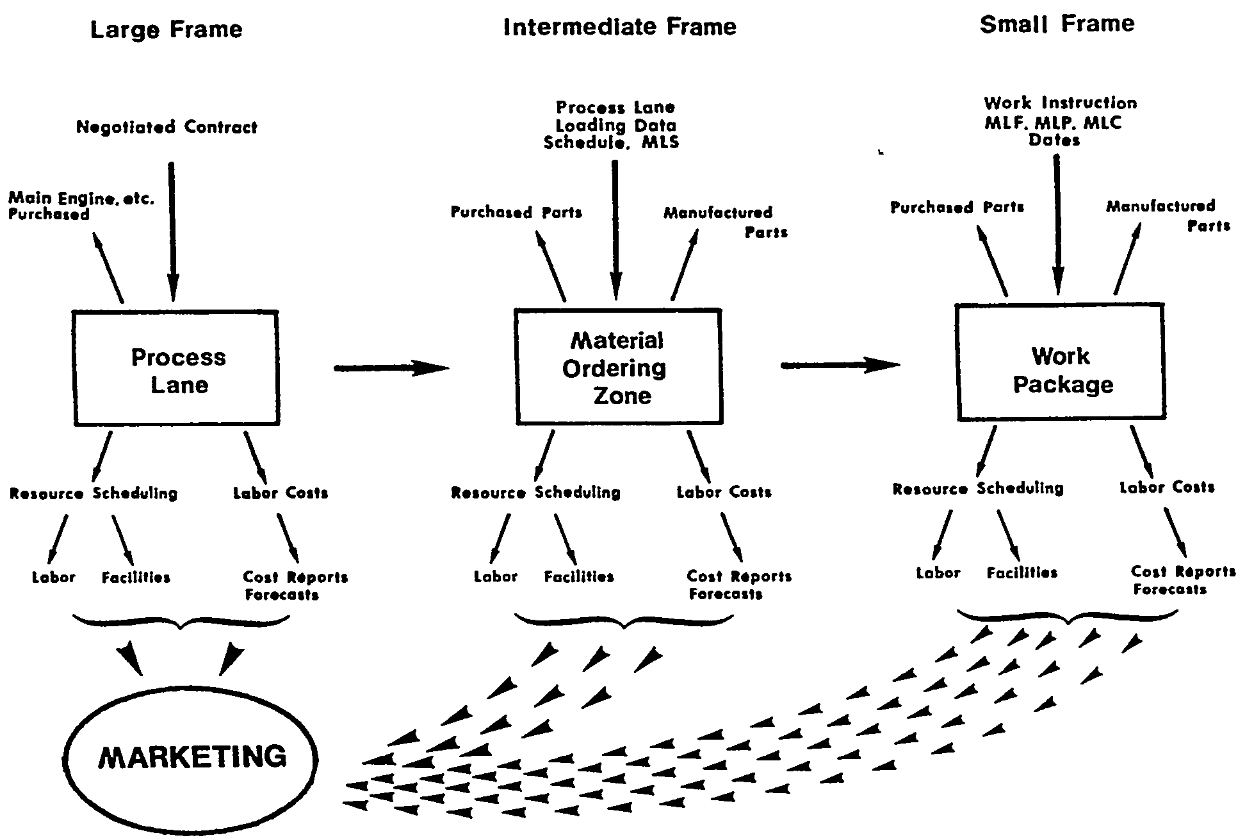

FIGURE 5: CONSTANT FEEDBACK TO MARKETING.

Projections of process lane utilization, using basic scheduling information, should be made in three categories. Firm commitments, for which contracts are in hand, should be treated as one category. A given percent utilization of a process lane for a given time period should be reserved for this work. A second category for high-probability work should be superimposed on the firm workload. This is for contracts being negotiated that have progressed to the point that 3D modeling is prudent. Finally, work that is-still uncertain, but being discussed should form the last category. Thus, prospective customers could readily be informed about the periods available in process lanes for their work.

The commercial airframe industry uses a similar reservation system, but needs only to consider one type of "process lane." the assembly line for a particular airplane model. A system like this would not be difficult to program, once a PWBS and the man-hours per material characteristic per process lane are in place and known. Note that the feedback from production and proauction control to marketing, and from different parts of the marketing organization, allow for a continual updating of actual practice. The feedback includes current productivity (such as man-hours/ton for flat block assembly), schedule adherence (such as actual status of process lane work), and process lane reservations (including probable work based upon negotiations with customers). This approach would provide an effective system that achieves some of the goals of a material requirements planning (MRP) system at the basic design/man-hour budget/schedule level, rather than at the detail level characteristic of commercial MRP applications.

CONCLUSION

Despite impressive development of computer hardware, CAD systems are not vet really addressing certain critical heeds. At-this time, successful marketing is the most important shipbuilding function. Consequently, in each shipyard, it is vital that a CAD system supports marketing with quick and accurate summaries of-the manufacturing system's current capability and availability to undertake various product alternatives that are of possible interest to customers.

Although computer capabilities exist to perform these functions, CAD systems built around traditional manufacturing approaches will not suffice. There is no alternative but to maintain (interim) product orientation with its focus on control through control of material. Thus, material, the only tangible entity, becomes the focal point for all data collection and feedback. Material volume equals work volume and thus ship cost/capability tradeoffs and facility utilization can be analyzed, evaluated and updated to provide-marketing functionaries with up-to-the-minute information. This information should be available regardless of the scope of any change in the manufacturing system.

Since there will always be another third-world country which will support its shipbuilding industry as a means to industrialize, from now on, the ability of other countries' shipbuilding industries to compete will be highly dependent on how well information is exploited. Thus the ability of CAD systems to constantly collect, process and distribute the right information to the right people is essential. Right now, CAD system developers should include data feedback to marketing as a high priority enhancement to current CAD capabilities.

REFERENCES

1. "A View of Japan's Industrial Engine," Daily Journal of Commerce, Seattle, Washington; 29 April 1992.

2. A. Sarabia and R. Gutierrez, "A Return to Merchant Ship Construction: The International Impact of the NSRP and American Technology," SNAME Journal of Shin Production, February 1992, pp. 28-35.

3. Patricia D. Taska, "The Updated REAPS AUTOKON System,". REAPS 2nd Annual Technical Symposium Proceedings, 1975.

4. Lonnie W. Lowery, "Use of SPADES System During the Engineering, Design, and Detail Phases," REAPS 2nd Annual Technical Symposium Proceedings, 1975.

5. D. R. Patterson, "BRITSHIPS 2 - A Computer Aided Design and Production System Using Computer Graphics," IREAPS 10th Annual Technical Symposium Proceedings, 1983.

6. Filippo Cali and Floyd Charrier, Jr., "SPADES Integrated Approach to Structural Drawings and Lofting," IREAPS 10th Annual Technical Symposium Proceedings, 1983.

7. 1967 Annual Report of Shipbuilding Development, The Society of Naval Architects of Japan, "Statistical control 'epoch makingly' improved quality, laid the foundation of modern ship construction methods and made it possible to extensively develop automated and specialized welding."

8. M. Ijichi, S. Kohtake, and H. Kashima, "Computer Applications To Accuracy Control In Hull Construction," Computer Applications in the Automation of Shipyard Operation and Ship Design, V, 1985.

9. T. Inoue, H. Shirakami, K. Shishida, Y. Moriya, "HICADEC: Integrated CAD/CAM System with 3D Interactive Data Processing Architectures for CIMS in Shipbuilding," Computer Applications in the Automation of Shipyard Operation and Ship Design, VI, 1989.

10. Y. Okumoto, A. Ando, Y. Niiro, and K. Hiyoku, "Computer-Aided Engineering System For Hull Structure - FRESCO-S", Computer Applications in the Automation of Shipyard Operation and Ship Design, VI, 1989.

11. Mitch Ratcliffe, "The Pleasure Machine," MIT Alumni Technology Review, Spring 1992.

12. Ichinose, Y., "Improving Shipyard Production With Standard Components and Modules," SNAME Spring Meeting/STAR Symposium Proceedings, April 26-29, 1978.

13. C.S. Jonson and L.D. Chirillo, "Outfit Planning," National Shipbuilding Research Program, December 1979, p. 30.

14. L.D. Chirillo, "Flexible Standards: An Essential Innovation in Shipyards," SNAME Journal of Ship Production February 1991.

15. H. Kawaguchi, R. Matsuda, H. Kakuno, and M. Shigematsu, "New Integrated Engineering Systems For Hull Structure and Piping," Computer Applications in the Automation of Shipyard Operation and Shin Design, V, 1985.

16. KCS Systems, "A New Dimension in Shipbuilding," Product Information Brochure, 1991.

17. Calma," Dimension III, Project Review Software", Product Information Brochure, 1989.

18. D. W. Billingsley and J.C. Ryan, "A Computer System Architecture for Naval Ship Design, Construction. and Service Life Support," SNAME Transactions Vol. 94, 1986.

19. Kaj Johansson, "Integration of CAD/CAM and Management Information Systems," Computer Applications in the Automation of Shipyard Operation and Shin Design, VI, 1989.

20. Eric W. Stewart, "The Use of Computers in Establishing a Company-Wide Perspective Toward Advanced Ship Production, SNAME Journal of Ship Production, November 1989.

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